SYSTEMATIC SEARCH FOR SHORT-TRANSIENTS AND PULSATION EVENTS FROM INTEGRAL SURVEY DATA

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ABSTRACT

The imaging instruments on board INTEGRAL have wide fields of view and high time resolution. Therefore, they are ideal instruments to search for pulsating sources and/or transient events. We are systematically searching for pulsations and transient events from known and serendipitous sources in the Galactic Plane Scan (GPS) and Galactic Center Deep Exposure (GCDE) core program data. We analyze the standard pipe-line data using ISDC Off-line Science Analysis (OSA) system, so that our results are reproducible by general guest users. In this paper, we describe our system and report preliminary results for the first year of operation.

Key words: INTEGRAL; pulsars; fast transients; survey.

1. SCIENTIFIC OBJECTIVE

The wide fields of view and the dithering strategy of INTEGRAL observations enable us to carry out a systematic survey of a large area of the sky. The INTEGRAL Science Data Center (ISDC; Courvoisier et al. 2003), monitors the observations of the instruments with the *Quick Look Analysis* (QLA) software. This allows us to systematically search for bright transient events, as well as monitoring the primary targets of the observation, within a few hours of receiving the telemetry (Shaw et al. 2004).

However, the QLA carries out analysis only on the Science Window (ScW) basis. Each ScW lasts about 30 minutes, and analysis at shorter timescales, which would take too much CPU time and disk space, is not feasible with QLA. Therefore, we may miss short transient events, which are likely to be smeared if integrated for the entire ScW. Also, QLA does not search for pulsations, and fast pulsars down to ∼msec periodicity may not be detectable unless event arrival time analysis is performed; such an analysis is not considered in the standard analysis pipe-line.

The INTEGRAL Burst Alert System (IBAS; Mereghetti 2003) produces real-time results of bright transient events; not only Gamma-ray bursts, but also other transient events at various timescales from milliseconds to minutes. However, IBAS directly accesses raw telemetry, and is not able to read the standard processed data. Also IBAS is not available to public.

To supplement the QLA, standard analysis and IBAS, we are developing a system to systematically search for transient events and pulsations from core program GPS and GCDE data. Our system will be publicly available as a part of ISDC OSA. In this paper, we describe the technical aspects of our project, and demonstrate the feasibility.

2. ANALYSIS METHODS

2.1. Transient events from known sources

We routinely run the standard pipeline analysis on the GPS and GCDE data. For the known and detected sources, we make ISGRI and JEM-X light curves with 100 second time-bin[1].

After the JEM-X and ISGRI light curves are made, we carry out statistical tests to search for variable

[1]We use ISDC executables "ii_light" and "j_src_lc" to create ISGRI and JEMX source light curves, respectively.

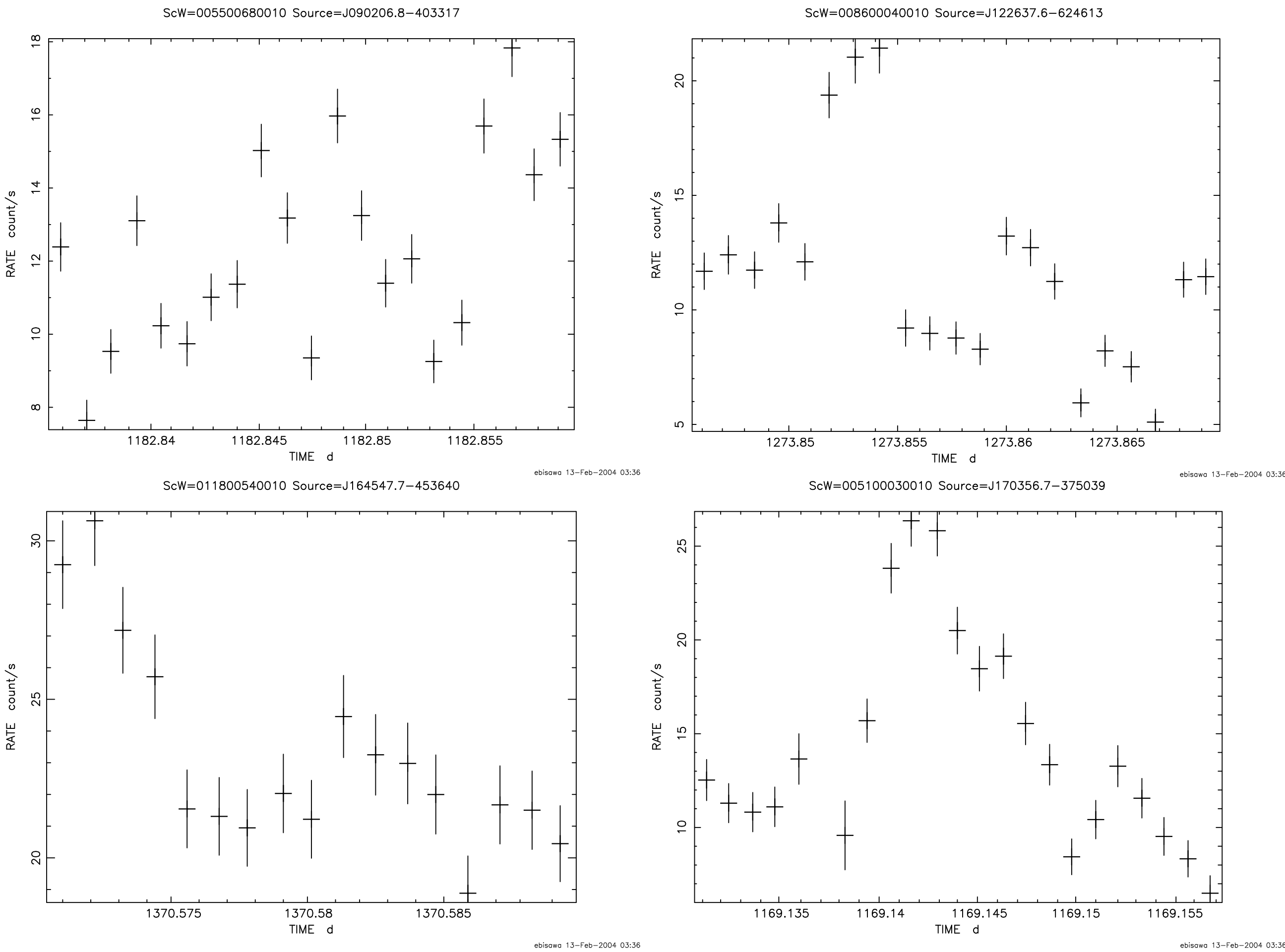

Figure 1. Example of JEM-X light curves of variable sources, which show significant variations within a single Science Window. Bin width is 100 seconds, and the light curves are shown for each Science Window.

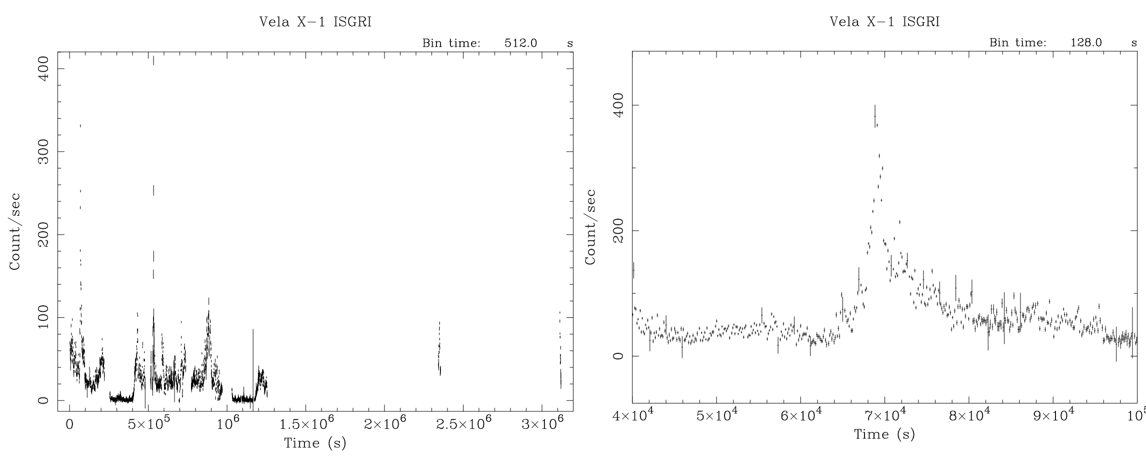

Figure 2. Left: ISGRI Vela X-1 light curve from TJD = 12970 to 13006 (where Truncated Julian Date = MJD - 40000). Bin-width is 512 sec, and the energy range is from 20 keV to 60 keV. Right: Expansion of the large flare at around TJD =12971. Bin-width = 128 sec.

events. In Figure 1, we show examples of JEM-X light curves with significant variations within one ScW. In this case, the search for variation is made for each ScW. Namely, we find only variations shorter than the length of a ScW.

Since each Scw is a single, stable pointing, these short-term variations are free from systematic effects that may be introduced by the observation dithering pattern.

In Figure 2, we show an example of the ISGRI Vela X-1 light curve. A prominent flare is seen at around TJD (Truncated Julian Date) = 12971 (Krivonos et al. 1994; Staubert et al. 2004).

2.2. New transient search

While IBAS systematically searches for strong gamma-ray bursts with IBIS, soft X-ray transients below ∼15 keV may be expected only by JEMX. Also, IBAS may not trigger weak gamma-ray bursts, which may be found in the off-line analysis.

To search for new short-term transients, which are not in the reference catalog, we need to carry out image deconvolution and do a source search for a much shorter duration than the ScW. Current OSA (v.3.1) is not really suitable for such a purpose, since a user Good Time Interval (GTI) has to be specified for each Observation Group *before* data correction and instrumental GTI calculation are made.

We adopt a new, more efficient data processing flow, which will be standard in the INTEGRAL archives and OSA 4.0 (Figure 3). In the new scheme, after the standard RAW, PRP, COR and GTI process, a merged event list is created for each ScW. Each event has physical arrival time (TIME column), as well as START and STOP times of GTI. The GTI extensions are included in the same file, therefore generic tools (such as xronos ftools, xselect) can read these event files.

After the event list is made for a ScW (which is typically 30 minutes or so), we define many short user GTIs, each 1 minute or so. By applying the short user GTI, we run OSA and create sky images for each ∼ 1 minute, and carry out a source search. Note that in this method the user GTI is specified *after* the Correction and instrumental GTI calculation step, so that we do not have to duplicate these processes for each user GTI.

We have already adapted OSA so that it runs on the merged event file, and have started to systematically search for new transient events in the GPS and GCDE data. We are evaluating sensitivity of ISGRI and JEMX for short transient events. Preliminary results suggest we may detect ∼ 50 mCrab transient source for one minute interval with both JEMX (5 – 30 keV) and ISGRI (20 – 60 keV).

2.3. Short pulsation search

To search for fast (e.g. ∼ millisecond) pulsations, we need to make event arrival time analysis without image deconvolution, since it is not practical to carry out deconvolution for such a short period. The ISDC tool “barycent” (since version 2.1) has been modified so that it can perform the barycentric correction on the event lists. To optimize the search for pulsations, we select events based on the Pixel Illumination Factor (PIF), which is the fractional area of each ISGRI pixel exposed to a source. The PIF takes values from 0 to 1, such that PIF=0 means this pixel is not sensitive to that source, and PIF=1 means this pixel is fully exposed to the source.

A standard and stand-alone tool `ii_pif_build` is used to calculate the ISGRI PIF for a given source. Once the PIF map is made, it is straightforward to filter event lists based on the PIF threshold (Figure 3). In Figure 4, we show an example of the PIF and PIF-based event filtering. By applying the PIF filter, we can reduce the background and optimize the signal to noise ratio. From experience, we choose PIF > 0.5 as the event selection criterion. A similar PIF creation tool is expected for JEMX too.

In Figure 5, we demonstrate the effect of PIF selection. In this example, we analyze ISGRI Crab pulsar data from ScW 010200380060. The events are folded with the apparent pulse-period (barycentric correction is not made) at 33.550 msec. We can see that, after the PIF selection, the background is substantially reduced and the pulse-shape is much more prominent. Note that the `fmaskfilt` ftool is used to carry out the ISGRI PIF selection.

We have confirmed our event timing analysis method by detecting pulsations from known pulsars such as Cen X-3. By combining JEMX and ISGRI, we will be able to study known pulsars and search for new pulsars in the wide energy range from ∼ 5 keV to ∼ 200 keV.

ACKNOWLEDGMENTS

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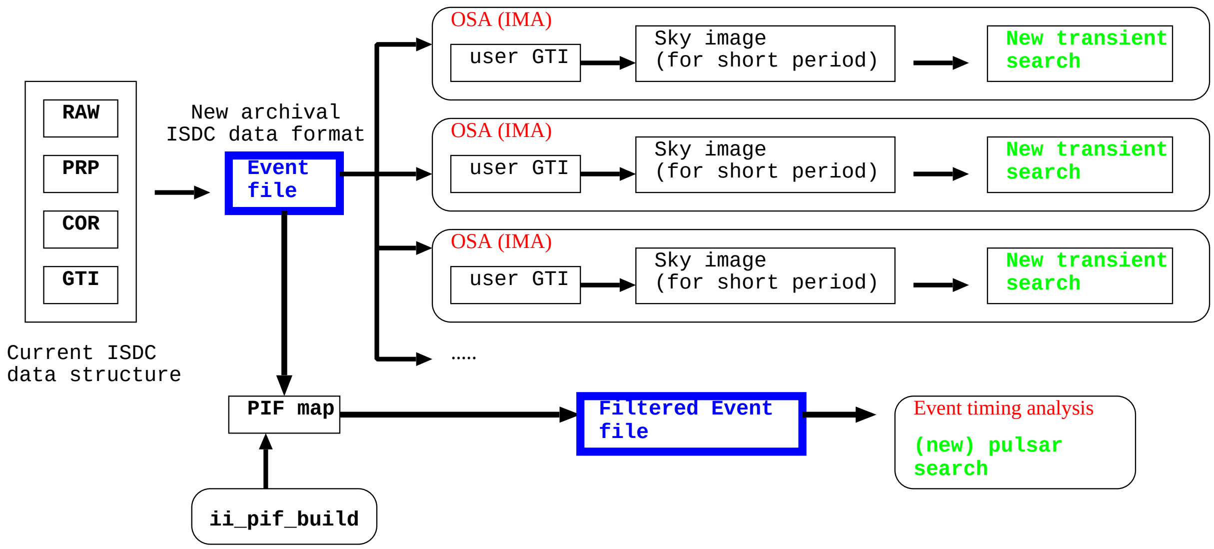

Figure 3. Analysis flow for our short transient search and pulsar search program.

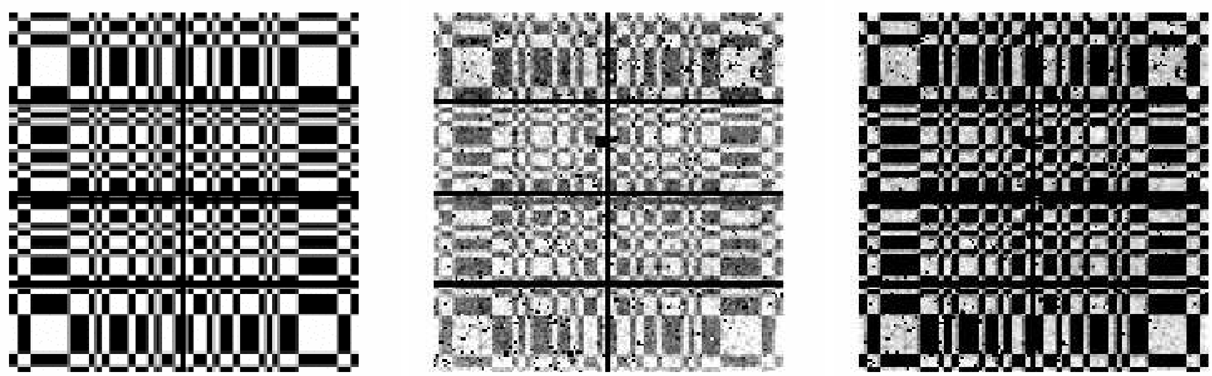

Figure 4. Left: ISGRI pixel Illumination Factor (PIF). Middle: Original detector image. Right: Detector image with pixels whose PIF values exceed 0.5. The data is from Science Window 010200380060 (Crab observation).

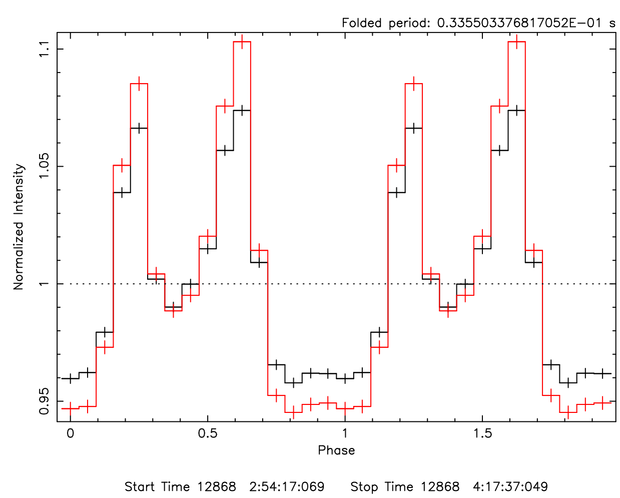

Figure 5. Folded pulse-profile of the Crab pulsar from ISGRI ScW 010200380060. Black is made from the original event file using all the events, and red is from the events whose PIF values exceed 0.5. Each profile is normalized so that the pulse-fractions relative to the average counting rates are plotted.